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# Performance of MIMO Downlink WiMAX at Application Layer

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# Introduction

- WiMAX performance evaluation for single antenna and multiple antenna techniques has received considerable attention by WiMAX researches and operators.
- Most of WiMAX capacity studies focus on PHY and MAC performance and to date only limited analysis has been presented on WiMAX goodput at higher layers.
- This paper evaluates the maximum total goodput for Single Input Single Output (SISO) and MIMO (both STBC and SM) in WiMAX, operating range and combination of traffic classes (UGS and rtPS) at Application Layer.

# PHY DL Data Rates and After Overhead

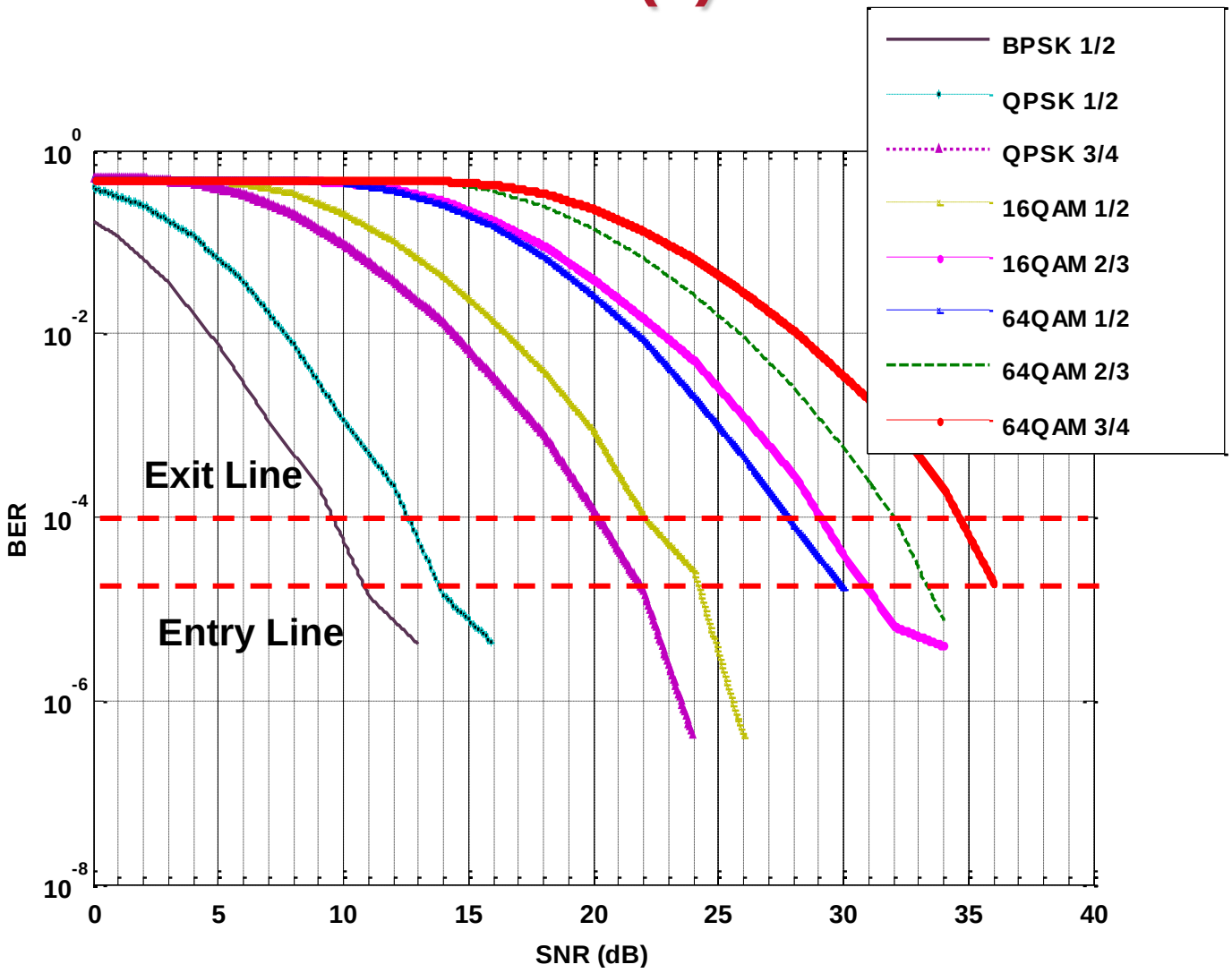
| Modulation and Encoding Rate | SISO and STBC (Mbps) | | SM (Mbps) | |
|---|---|---|---|---|
| | ***PHY Data Rates*** | ***After IP and MAC Overheads*** | ***PHY Data Rates*** | ***After IP and MAC Overheads*** |
| QPSK ½ | 3.571 | 3.393 | 7.142 | 6.786 |
| QPSK ¾ | 5.357 | 5.089 | 10.714 | 10.178 |
| 16QAM ½ | 7.143 | 6.786 | 14.286 | 13.572 |
| 16QAM ¾ | 10.714 | 10.179 | 21.428 | 20.358 |
| 64QAM ½ | 10.714 | 10.176 | 21.428 | 20.358 |
| 64QAM 2/3 | 14.286 | 13.571 | 28.572 | 27.142 |
| 64QAM ¾ | 16.071 | 15.268 | 32.142 | 30.536 |

**WiMAX DL PHY DATA RATES and THEIR DATA RATES AFTER CONSIDERING THE IP AND MAC OVERHEADS FOR SISO, STBC 2x2, SM 2x2 (PUSC, DL:UL[99:99])**

# Link Level Simulation (1)

- We perform SISO, SM 2x2, STBC 2x2 at link level to produce BER curves
- The parameters used are:
  - Spatial Channel Model Extension (SCME) and an urban micro 3GPP tapped delay line (TDL)
  - A correlation factor of 0.4
  - STBC Alamouti
  - A minimum mean square error (MMSE) receiver for SM-MIMO
- We set exit and entry thresholds at BER between $10^{-4}$ and $10^{-5}$ for the link adaptation

# Link Level Simulation (2)



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# System Level Simulation (1)

- The generated BER performance results are incorporated as SNR-BER look-up tables to compute burst errors for the instantaneous channel conditions and also for link adaptation
- The use of BER tables and threshold values realise the Qualnet link adaptation decisions more realistic.

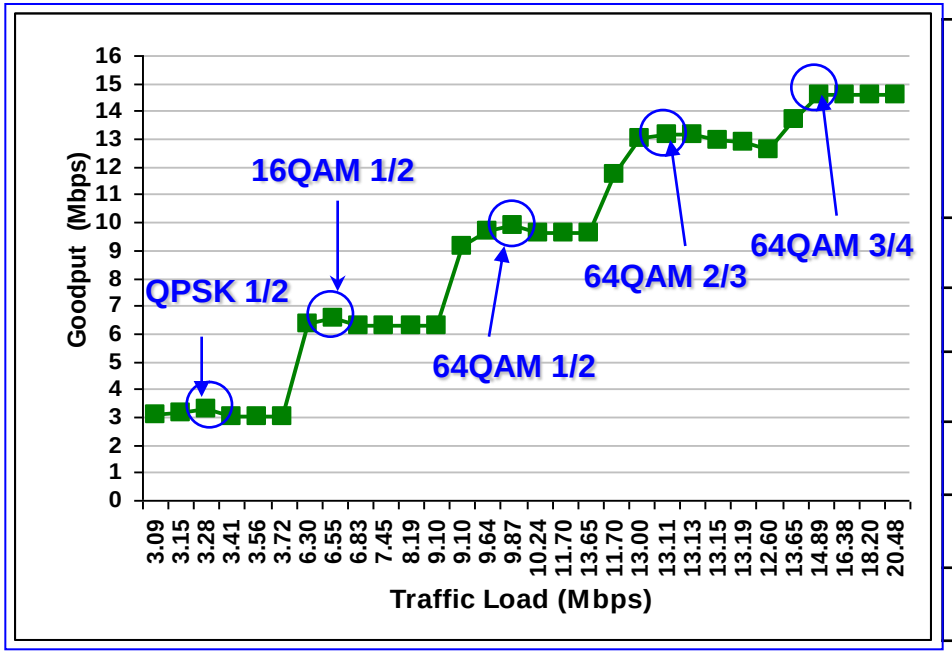
# Scenarios

- A BS communicates to a stationary SS with fixed-size data packets of 1024 bytes at Constant-Bit-Rate (CBR) which is performed across QPSK, 16QAM and 64QAM.
- The load is increased to saturation by increasing the packet rate; packet size is constant.
- The traffic load is calculated as:

$$Traffic\ Load\,(bps) = \frac{Packet\,Size\,(bytes)\,x\,8\,bits}{Packet\,Interval\,(s)}$$

- The scenario is then expanded to two types of scenarios (i) multiple SSs and (ii) multiple connections

# Simulation Results: SISO (1)



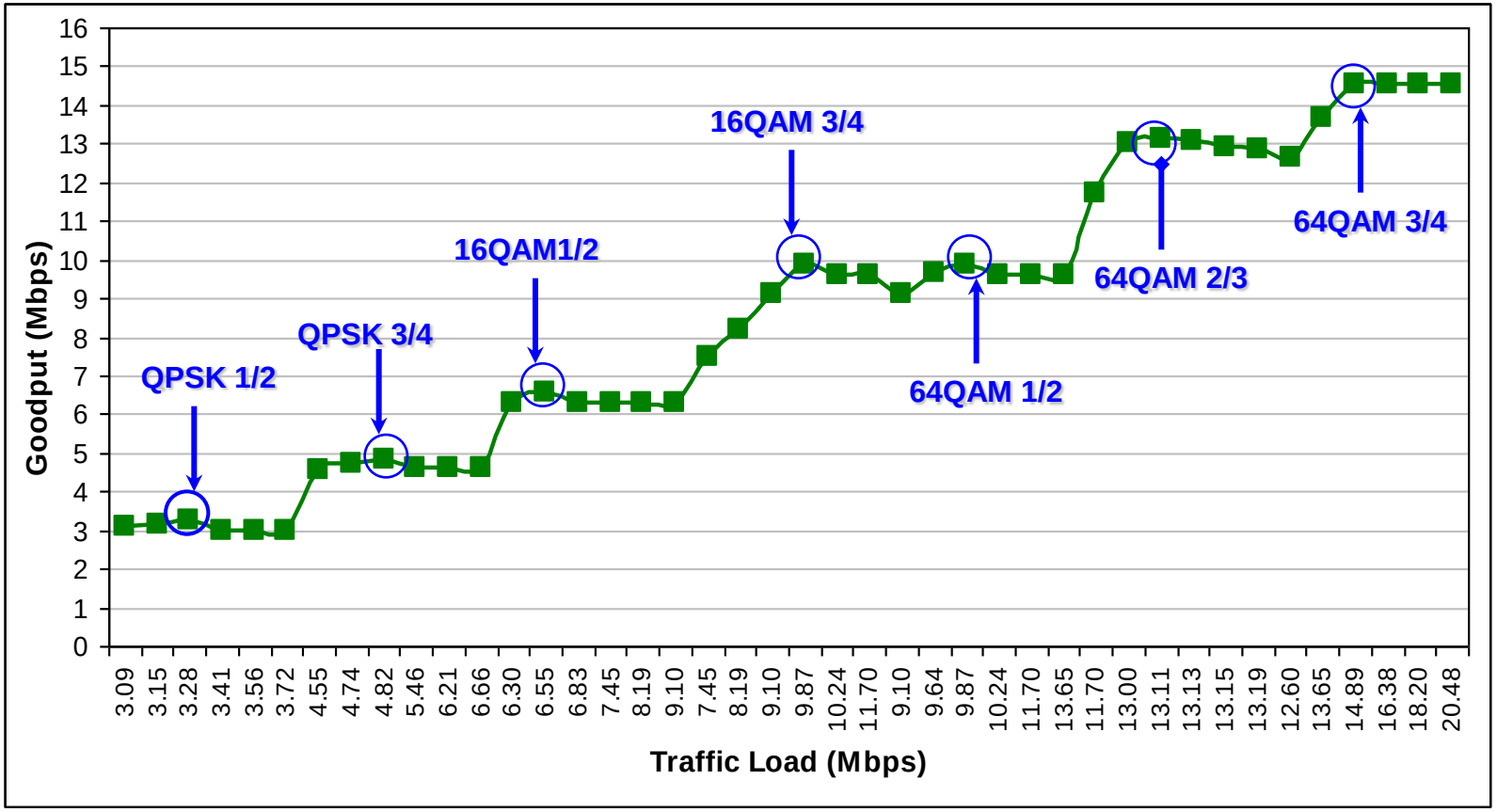

UGS goodput vs traffic load for SISO

| Traffic Load (kbps) | UGS Goodput (Mbps) | Packet Loss (%) | Average End-2-End Delay (ms) |
|---|---|---|---|
| 9102.22 | 9.11 | 0.01 | 20.30 |
| 9637.65 | 9.64 | 0.01 | 20.60 |
| 9869.88 | 9.88 | 0.01 | 21.26 |
| 10240.00 | 9.58 | 6.59 | 81.85 |
| 11702.86 | 9.58 | 18.26 | 100.67 |
| 13653.33 | 9.58 | 29.24 | 103.92 |

64 QAM ½ SISO

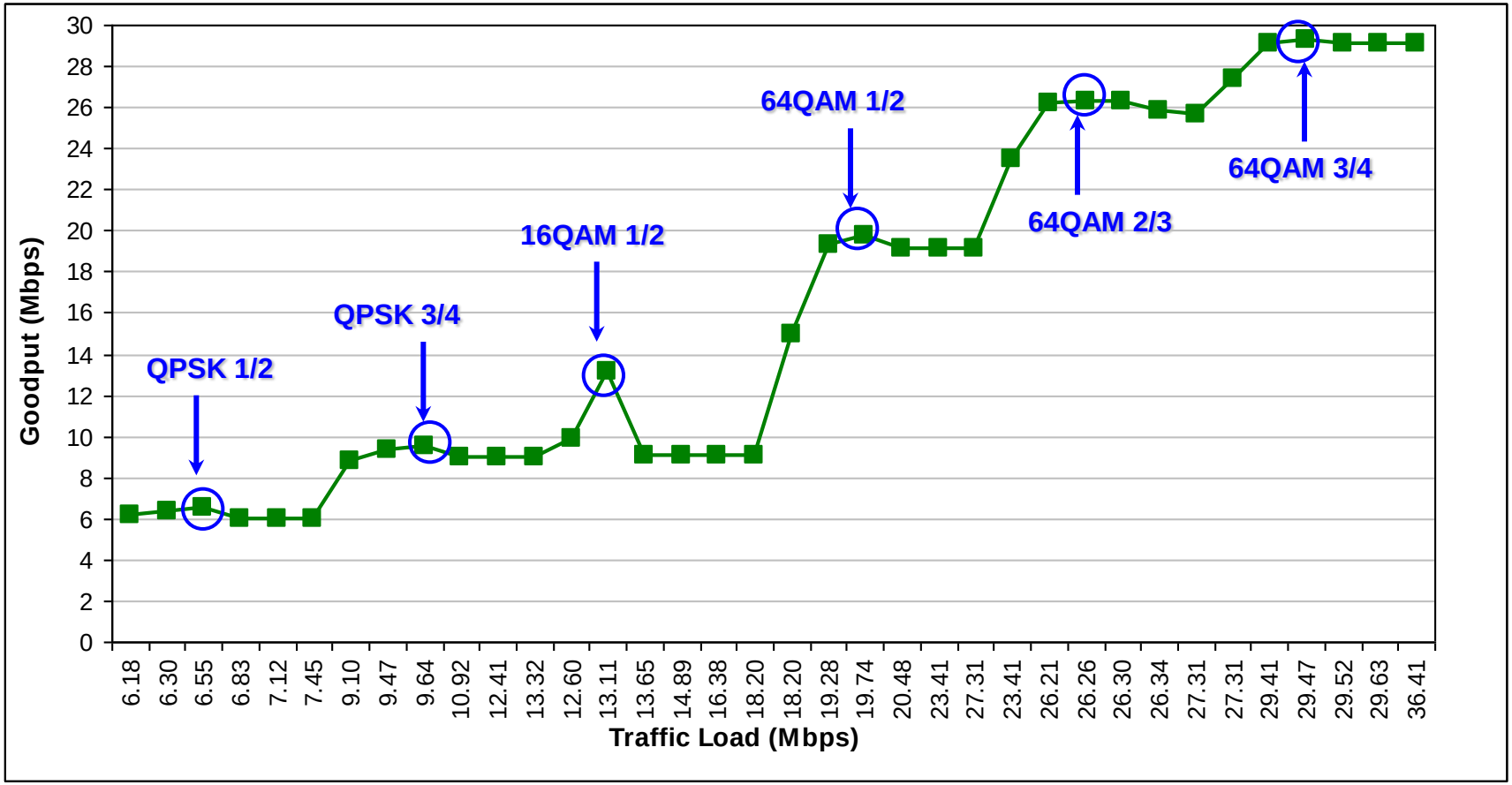
- The BS does not adopt all modulation and coding scheme due to some modes never provide the highest throughput in these channel conditions

# Simulation Results: STBC 2x2 (2)




**UGS goodput vs traffic load for STBC 2x2**

# Simulation Results: SM 2 x2 (3)



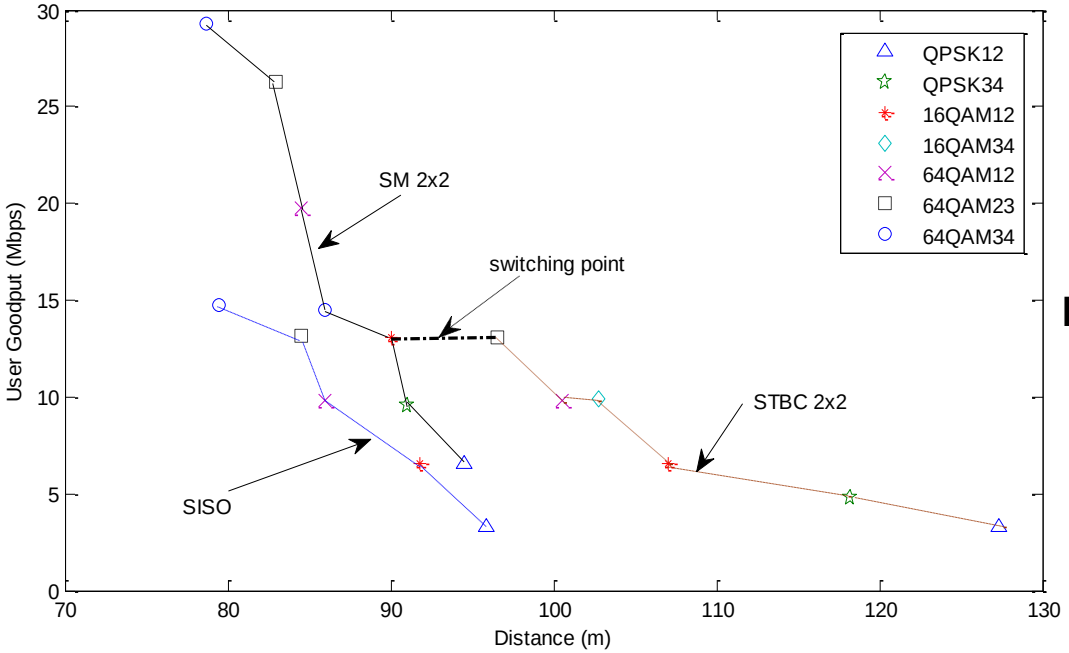

**UGS goodput vs traffic load for SM 2x2**

# Simulation Results: Maximum Goodputs (4)

| Modulation Coding Scheme | Antenna Technology | SNR (dB) | Maximum Traffic Load (Mbps) | Maximum User Goodput (Mbps) |
|---|---|---|---|---|
| QPSK ½ | SISO | 19.40 | 3.3092 | 3.2934 |
| | STBC | 6.25 | 3.2768 | 3.2701 |
| | SM | 20.54 | 6.5536 | 6.5504 |
| QPSK ¾ | SISO | | | |
| | STBC | 8.41 | 4.8188 | 4.8138 |
| | SM | 23.93 | 9.6376 | 9.5591 |
| 16QAM ½ | SISO | 23.16 | 6.5536 | 6.5504 |
| | STBC | 12.49 | 6.5536 | 6.5504 |
| | SM | 24.93 | 13.1070 | 13.1010 |
| 16QAM ¾ | SISO | | | |
| | STBC | 14.7 | 9.8698 | 9.8671 |
| | SM | | | |
| 64QAM ½ | SISO | 30.10 | 9.8698 | 9.8601 |
| | STBC | 16.07 | 9.8698 | 9.8601 |
| | SM | 32.15 | 19.7390 | 19.7300 |
| 64QAM 2/3 | SISO | 32.16 | 13.1281 | 13.1276 |
| | STBC | 17.22 | 13.1072 | 13.1038 |
| | SM | 34.75 | 26.2986 | 26.2752 |
| 64QAM ¾ | SISO | 41.23 | 14.7603 | 14.7324 |
| | STBC | 30.12 | 14.8945 | 14.5392 |
| | SM | 42.75 | 29.4676 | 29.2873 |

Max. goodputs in the range of 94.5% to 97.0% of the theoretical data rates due to packet losses during transmission

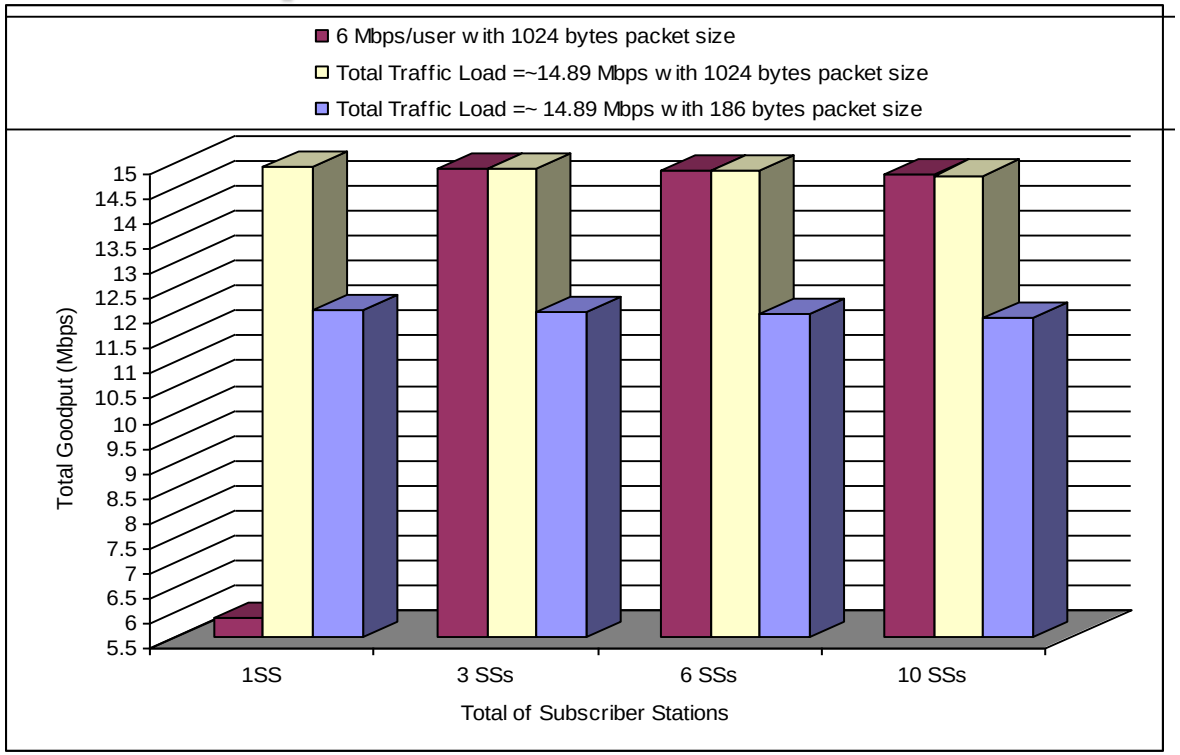
# Operating Range Analysis




**Maximum User Goodput vs. Distance**

- **SISO and STBC 2x2 achieve similar maximum goodput, but STBC operates at greater range than SISO due to the spatial diversity**
- **SM MIMO 2x2 doubles the achievable maximum goodput at shorter ranges since it needs a higher SNR for enhanced performance**
- **After 90m, the network switches from SM MIMO 2x2 to STBC 2x2 to achieve better performance and also broader cell coverage**

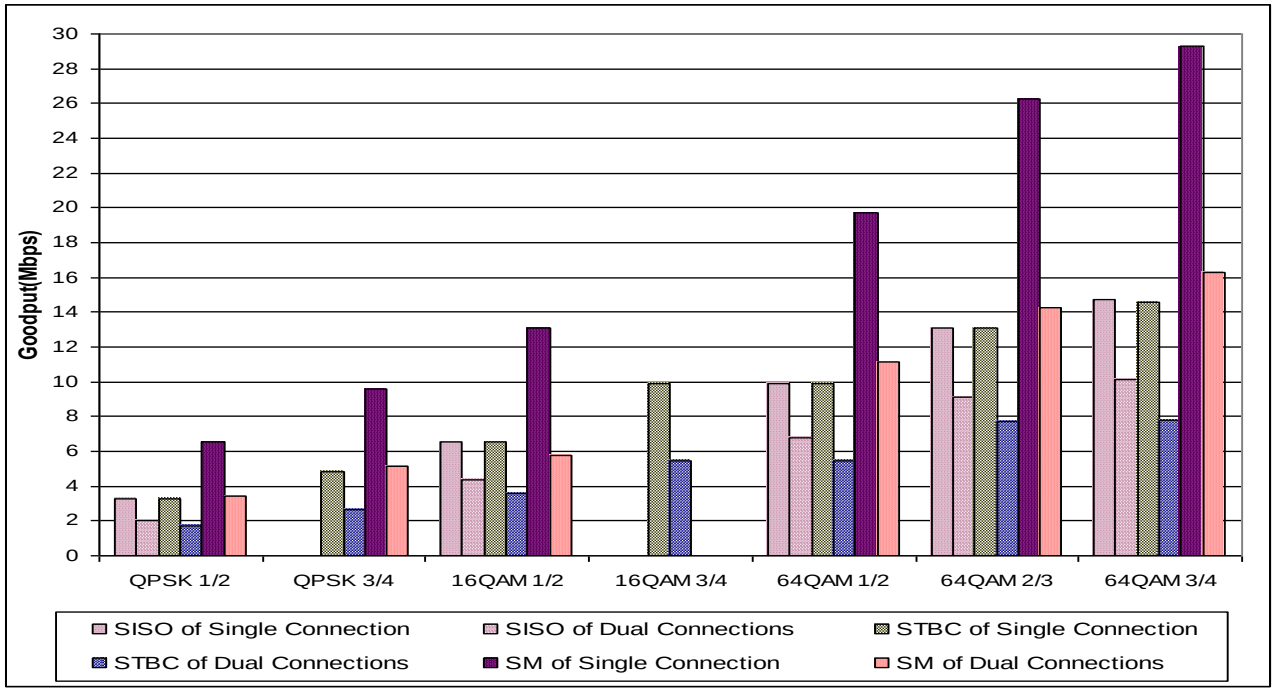
# Multiple Subscriber Stations




**Goodput performance for multiple subscriber stations for 64QAM ¾ of STBC**

- **The achievable maximum goodput drops because of (i) an increased number of users in the cell (more users generates more overheads) and (ii) the size of packet sizes (the smaller packet size generates more overheads)**
- **Once the cell achieves the maximum goodput, the total traffic load is no longer affects the cell performance and every user achieves lower goodput when the cell consists of more users**

# Combination of Traffic Classes




**UGS Max Goodput for a single connection and UGS Goodput after assuming an additional rtPS connection**

The previous achievable maximum UGS goodput inevitably decreases between 51% and 58% of the one achieved in a single connection for SISO, STBC and SM due to sharing the resources with the rtPS connection

# Conclusion

1. The achievable maximum goodput for a single user with CBR traffic is found to be between 94.5% and 97.0% of the theoretical data rates.
2. STBC 2x2 operates at greater range than SISO though they have similar maximum achievable goodput.
3. SM MIMO 2x2 achieves maximally up to ~30 Mbos at ~79 m from the BS whilst STBC achieves a better goodput after ~90 m from the BS.
4. A WiMAX system can sensible switch from SM to STBC at a distance of ~90 m
5. When having dual connections (UGS and rtPS), the maximum goodput of UGS is dropped to 51% and 58% depending on the antenna mode and MCS types.

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# Any Questions?